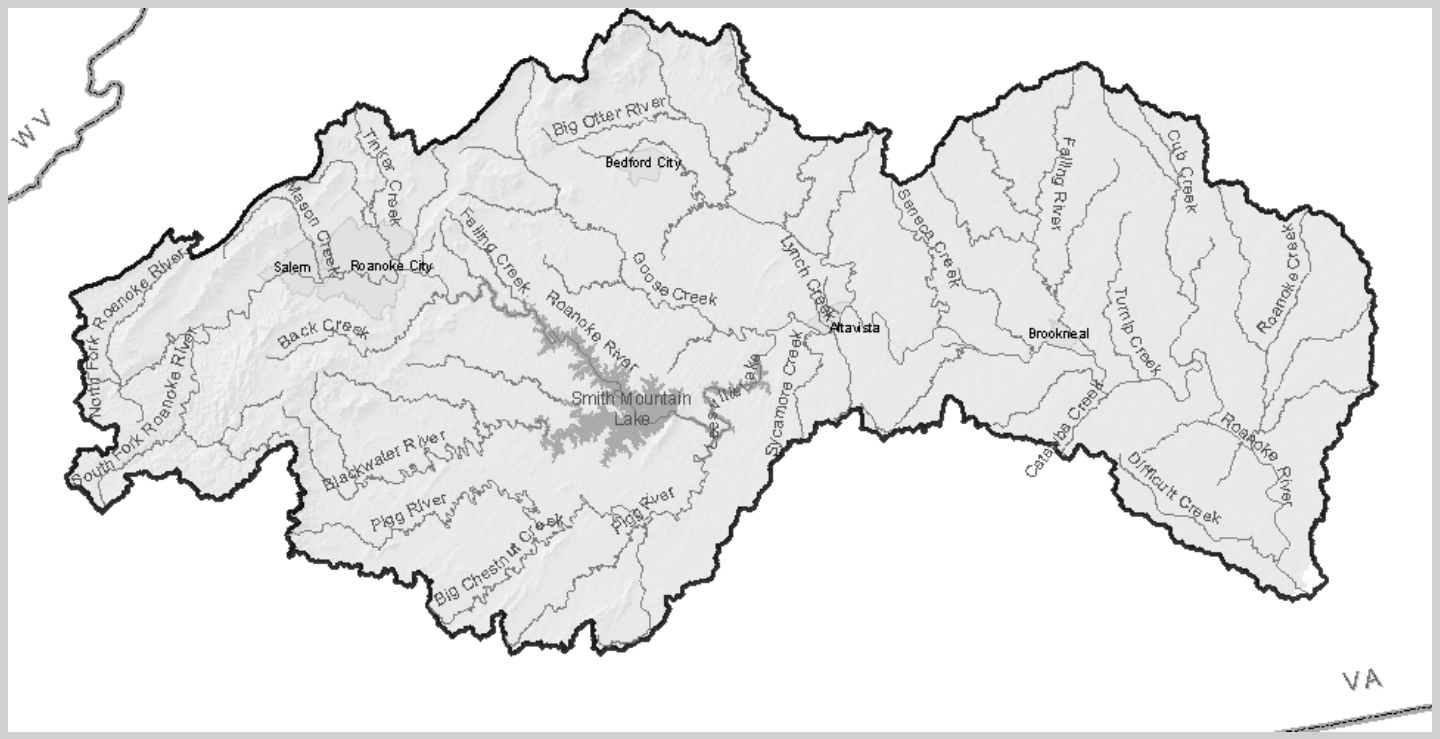
Roanoke/Staunton River PCB Model

February 3, 2009 TAC meeting



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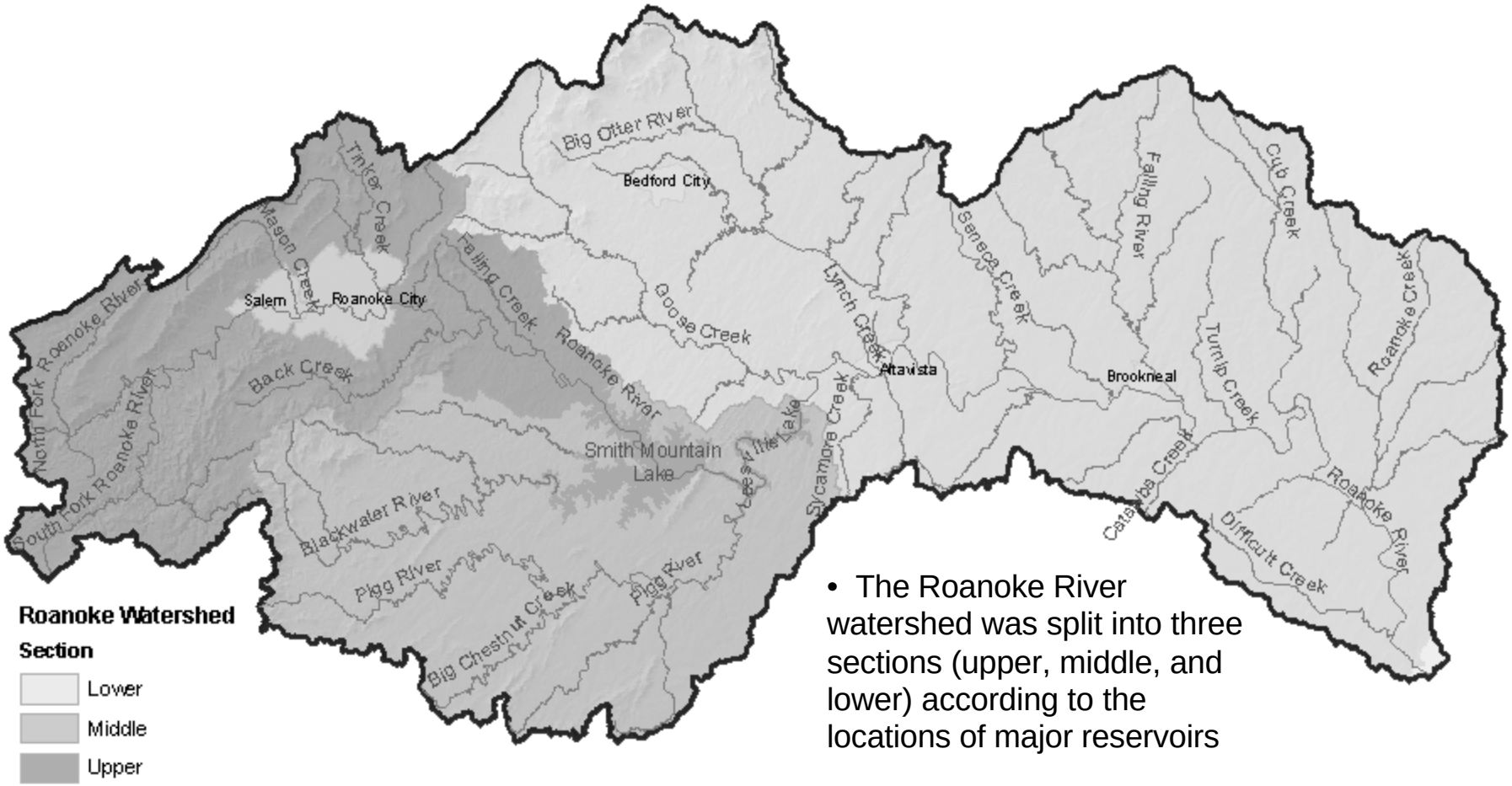
TMDL Model Development
Overview

LSPC watershed model was configured to simulate PCB loading and fate processes in the Roanoke River watershed for the purposes of calculating a PCB TMDL. Important components to model development included:

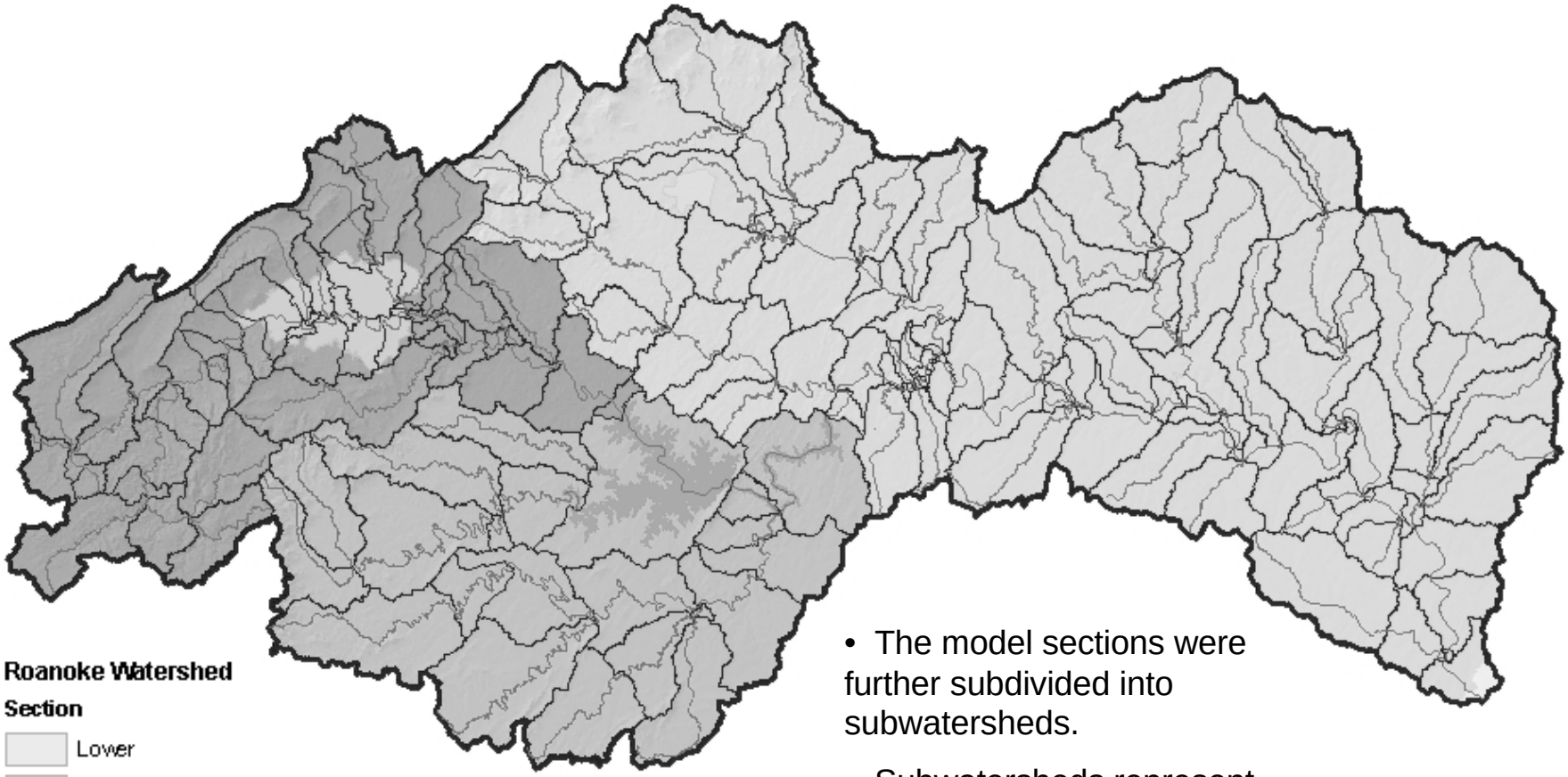
- Roanoke River watershed model sections
  - Upper, middle, and lower
  - Subwatershed delineation
- PCBs representation
  - Total PCBs
  - Dissolved and sediment-associated states and model parameterization
  - Fate processes (transport, burial, and re-suspension)
- Model PCB sources
  - Contaminated sites (contaminated upland soils)
  - Facility point sources
  - Contaminated river/stream sediments
  - Direct aerial deposition to river/stream segments
- Watershed BAF
  - PCB TMDL endpoint(s)

Watershed Model Sections



- The Roanoke River watershed was split into three sections (upper, middle, and lower) according to the locations of major reservoirs

Watershed Model Sections



- The model sections were further subdivided into subwatersheds.
- Subwatersheds represent the scale at which model simulations take place

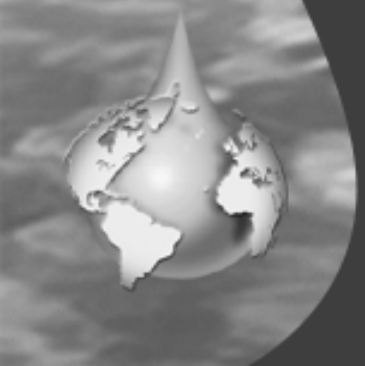
Watershed Model Sections

Watershed sections represented in the model include:

- Upper—Roanoke arm of Smith Mtn. L. upstream to Headwaters
- Lower (Staunton)—Dan R. confluence upstream to Leesville Dam
  - Together these sections include the 1998 303(d) impaired segments

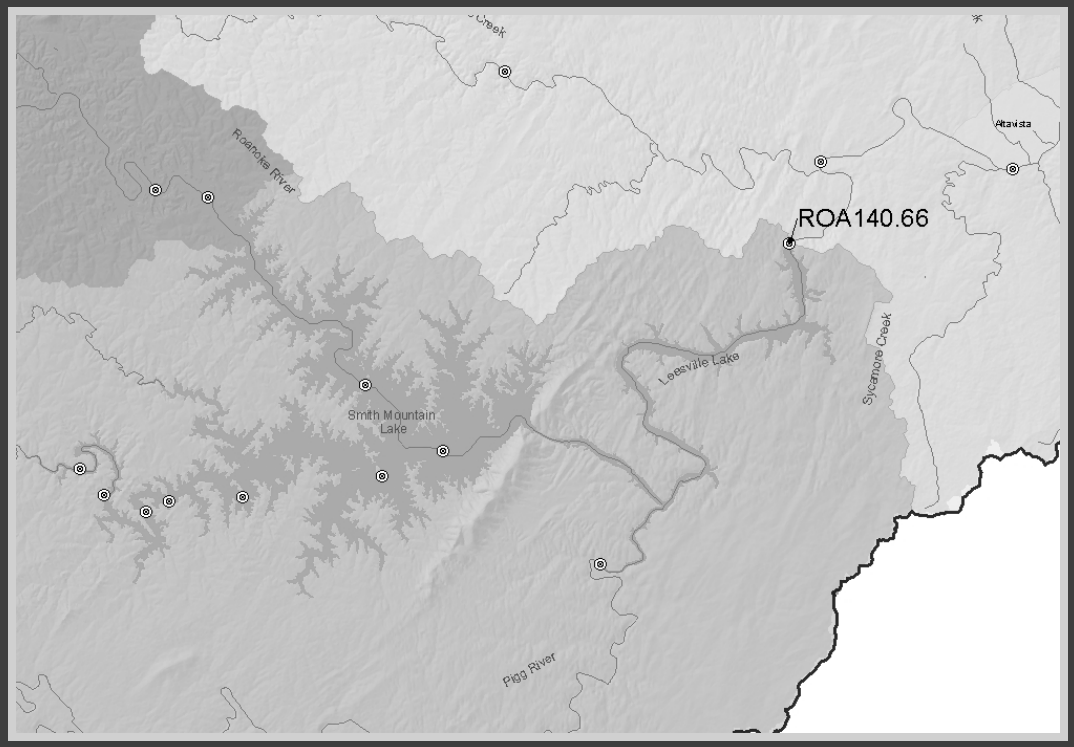
Watershed sections not represented include:

- Middle—drainage area of Roanoke R. mainstem from Leesville L. upstream to Roanoke arm of Smith Mtn. L.
  - Middle section is included in model subwatershed delineation
  - Includes 2008 303(d) impaired segments (Blackwater River and Smith Mtn. L.)



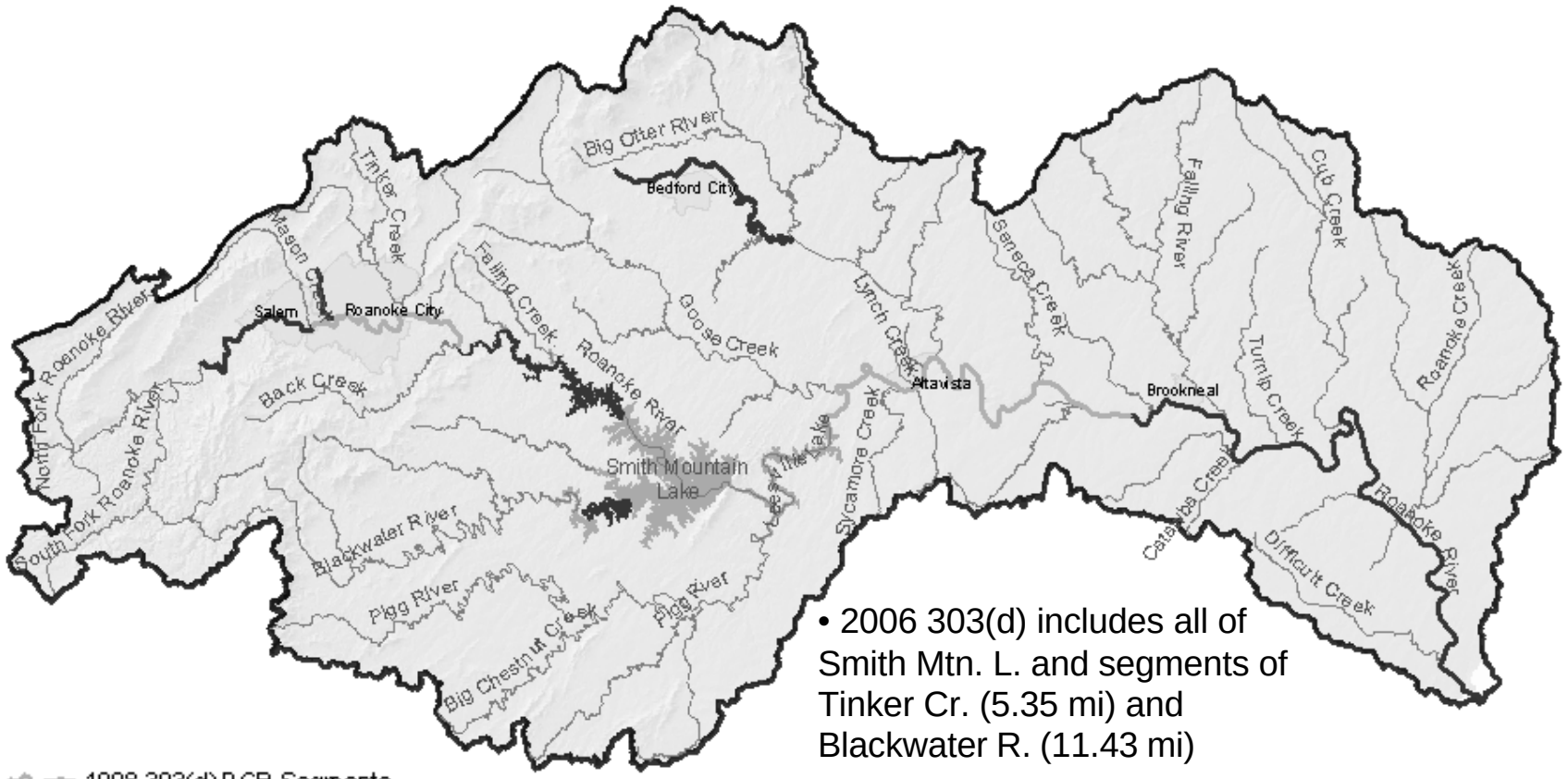
Watershed Model Sections

- Upper and lower sections are linked in the model using Leesville Dam discharge data and PCB fish tissue data at station ROA140.66 located on Leesville L. to calculate a flow and load time series
  - PCB fish tissue data converted to water concentrations using watershed BAF



Watershed Model Sections

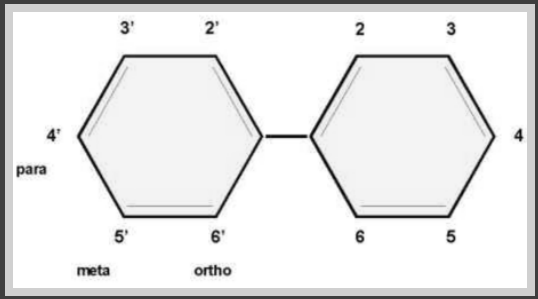
Impaired Waterbodies



- 2006 303(d) includes all of Smith Mtn. L. and segments of Tinker Cr. (5.35 mi) and Blackwater R. (11.43 mi)
- 2008 303(d) includes 14.25 mi segment of Cub Cr.

PCB Representation
Overview

- PCBs are a group of chemical species with same basic chemical structure—two bonded phenyl rings substituted with chlorine



- PCBs are grouped according to the degree of chlorination
  - maximum of 10 chlorine atoms can be present on a PCB molecule
  - 10 PCB groups or homologs corresponding to the # of chlorines

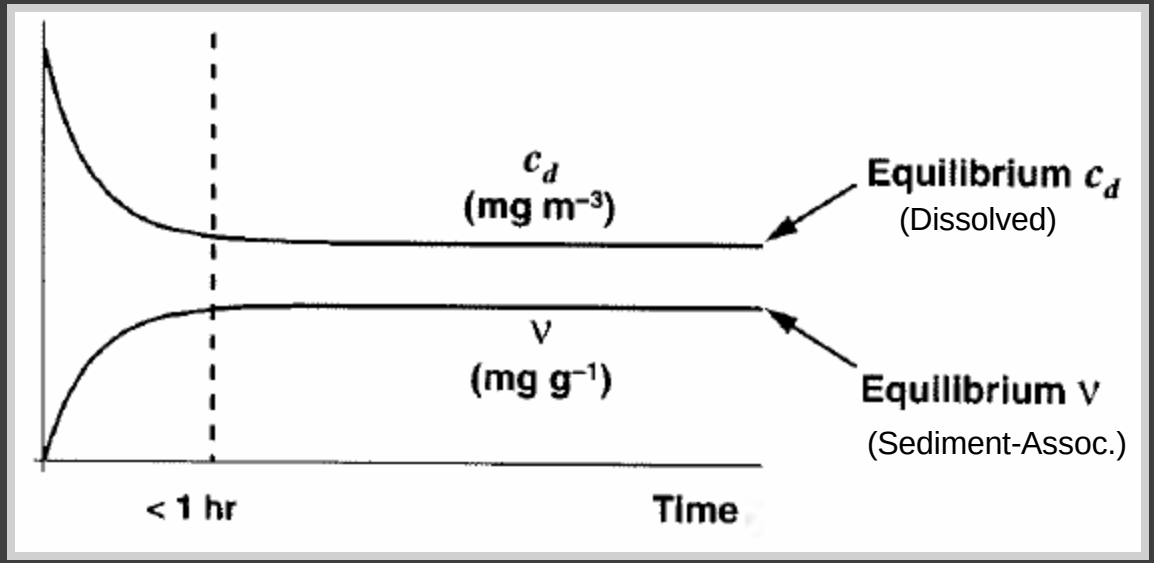
- The behavior of PCBs in an aqueous environment with organic components (sediment) is affected by degree of chlorination or homolog group

PCB Representation
Total PCBs

- Watershed Model simulates total PCBs (the sum of all homologs)
- To capture variability in PCB homolog behavior, components of the watershed model are assigned a representative PCB homolog (weighted average) based on monitoring data grouped at a specific scale
- Components of the watershed model include:
  - Stream segments
    - Scale: Roanoke River model sections (upper and lower)
  - Streambed sediments
    - Scale: Roanoke River model subwatersheds
- Model component are parameterized according to the assigned representative PCB homolog
  - Total PCBs within that component behave according to the representative PCB homolog

PCB Representation
Dissolved vs. Sediment-Associated

- The chemical behavior dependant on PCB homolog that is relevant to the PCB model is in-stream adsorption and desorption
- Adsorption-desorption describes how PCBs equilibrate/partition between sediment-associated and dissolved states
- All things being equal, > TSS concentration, > PCB sediment-association



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PCB Representation
Parameterization

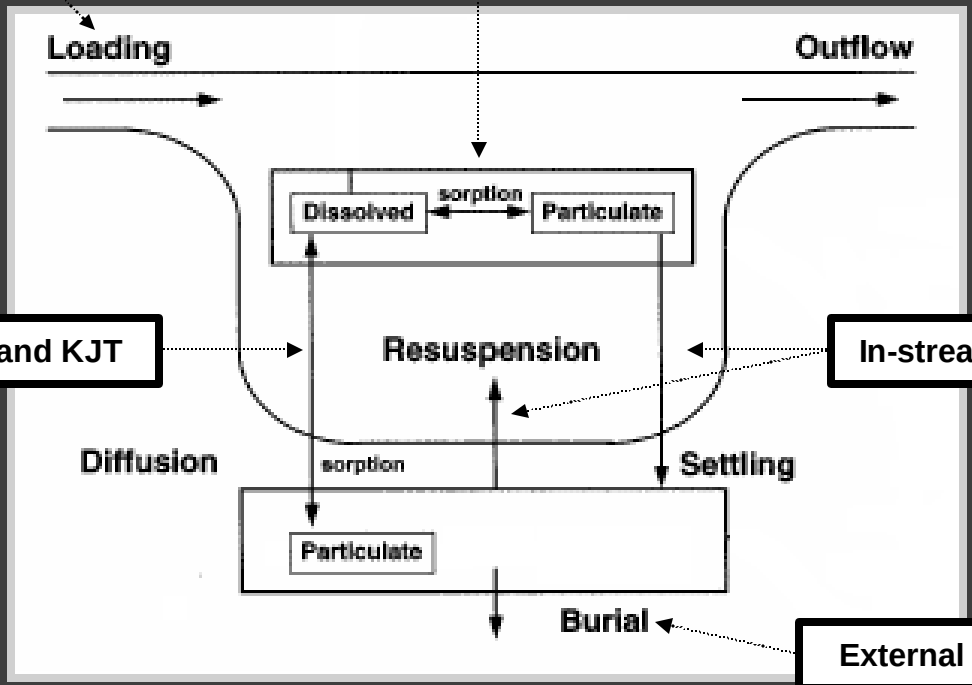
- Two model parameters control the adsorption-desorption process:
  1. Partition coefficient (K_d): the ratio of the chemical sediment-associated concentration to dissolved concentration at equilibrium
  2. Transfer rate (KJT): the rate at which equilibrium is reached
- The greater the K_d value the greater the tendency to be sediment-associated
  - K_d increases with increased PCB chlorination (higher homologs)
- The greater the KJT value the faster equilibrium is achieved
  - KJT decrease with increased PCB chlorination
- The representative homolog assigned to the watershed model components was used to parameterize K_d and KJT at the assigned scale
  - Stream segments
    - Scale: Roanoke River model sections (upper and lower)
  - Streambed sediments
    - Scale: Roanoke River model subwatersheds

PCB Representation

Model Fate Processes

- **Point Sources**
- **Contaminated soils**
- **Contaminated sed**
- **Aerial deposition**

Stream K_d and KJT



Sediment K_d and KJT

In-stream hydraulics

External rate

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Model PCB Sources

- Model PCB sources include:
  - Contaminated sites (contaminated upland soils)
    - Sites identified by VADEQ
    - Site area estimated from available GIS data
    - Soil PCB concentrations estimated from available monitoring data
    - PCB loads are sediment associated and transported to streams during modeled soil erosion events (storms)
  - Facility point sources
    - Include outfalls monitored as part of VADEQ PCB special study
    - PCB loads calculated from monitoring results concentrations and DMR flows
  - Contaminated river/stream sediments
    - Sediment PCB concentrations assigned at the subwatershed scale based on available monitoring data
  - Direct aerial deposition to river/stream segments
    - The Chesapeake Bay Program Regional PCB atmospheric deposition rate was applied to the entire watershed

Watershed BAF
Overview

- A Bio-Accumulation Factor (BAF) defines the susceptibility of an organism to accumulate and maintain pollutant concentrations in its tissues
- When developed for aquatic species, BAFs represent the ratio of a pollutant concentration in an organism's tissue to the pollutant concentration in the surrounding water
  - The > the BAF, the > the tendancy of the organism to accumulate and retain the pollutant
  - A species BAF can be used as a multiplier to convert a species pollutant tissue concentration to a water column concentration

Watershed BAF
TMDL Endpoints

- BAFs for resident fish species were calculated separately for the upper and lower Roanoke River watershed sections
  - Smith Mtn. Lake and Leesville dams act as a barrier between the two
  - Total PCB homolog composition between the two varies
- Monitoring data used for BAF calculations included:
  - 2007–2008 special study water quality monitoring data
  - 2006 fish tissue monitoring data
- Based on considerations of the robustness of species representation in monitoring data and PCB accumulation susceptibility, carp was selected as the critical BAF species
- The VADEQ fish tissue screening level for PCBs (54 ppb) was converted into TMDL endpoints for the upper (0.36 ng/L) and lower (0.09 ng/L) Roanoke River watershed sections using the associated median carp BAF